

# Tracking a CME and CIR as they travel from the Sun passing Venus, Earth, Mars and Saturn

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# How do solar transients propagate through the solar system?

Understanding complex solar storms and evolving solar transients requires multipoint in-situ & remote observations (Möstl et al. 2012, Rouillard et al. 2009, Williams et al. 2011)

Modelling can also provide extra information (e.g. Falkenberg et al. 2011, Jian et al. 2011)

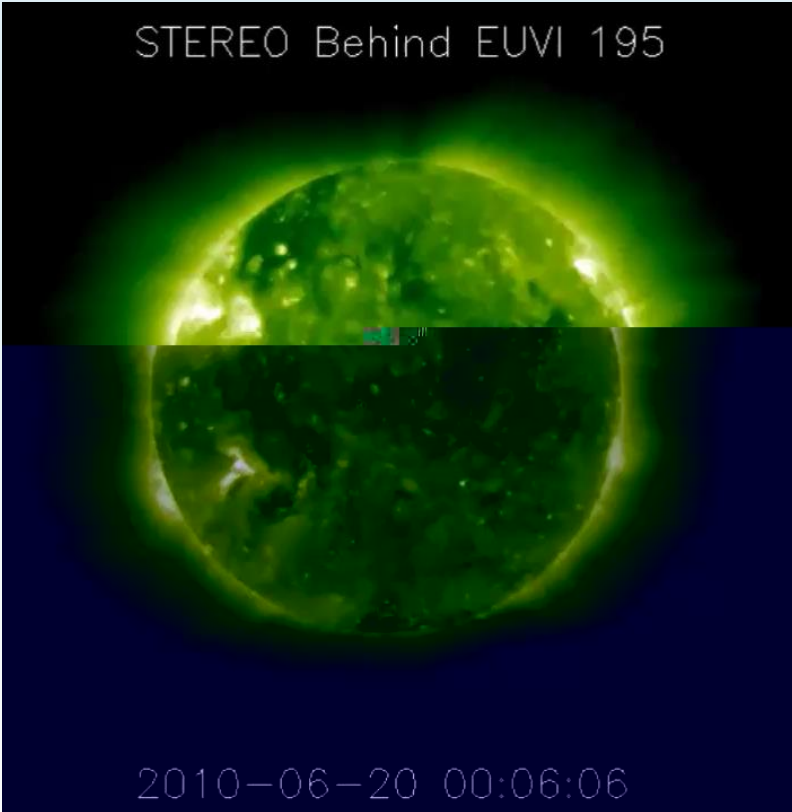
In the outer solar system, tend to see impacts of solar transients

In this study I have observed a CME and a CIR travelling through the solar system, from Venus, to STEREO-B, Mars, the Earth and Saturn.

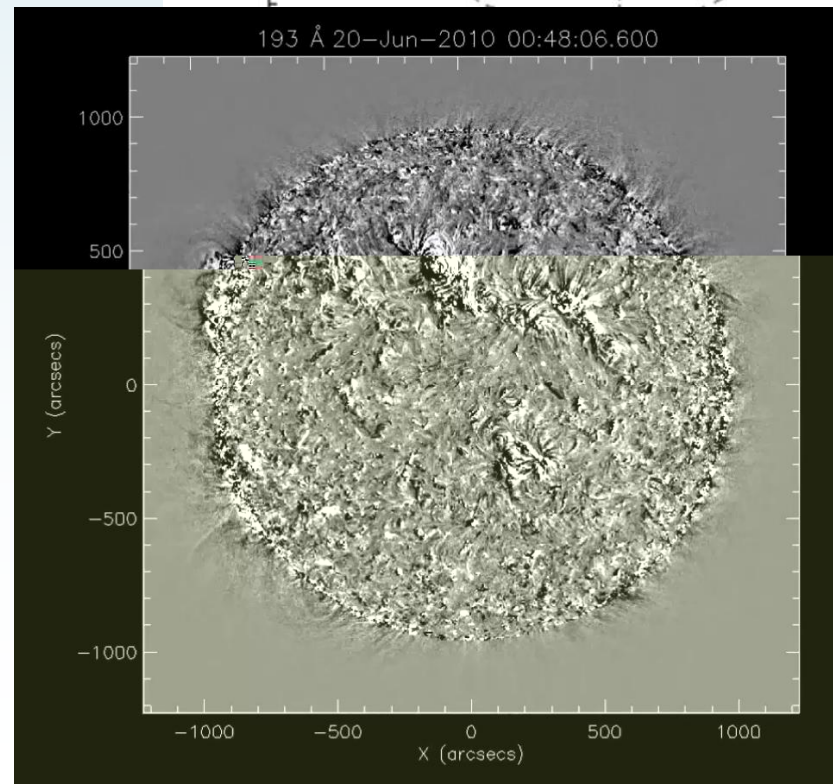
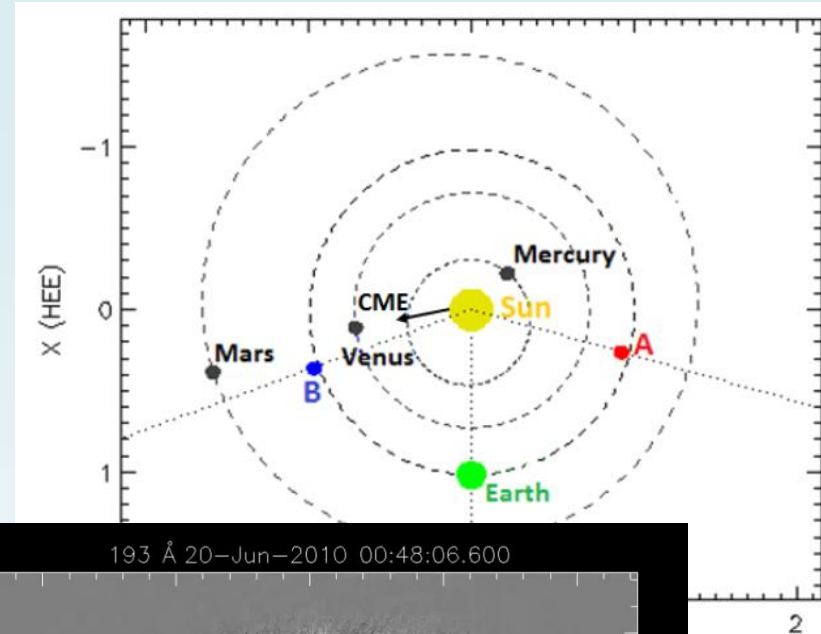


# CME on 20 June 2010

STEREO Behind EUVI 195



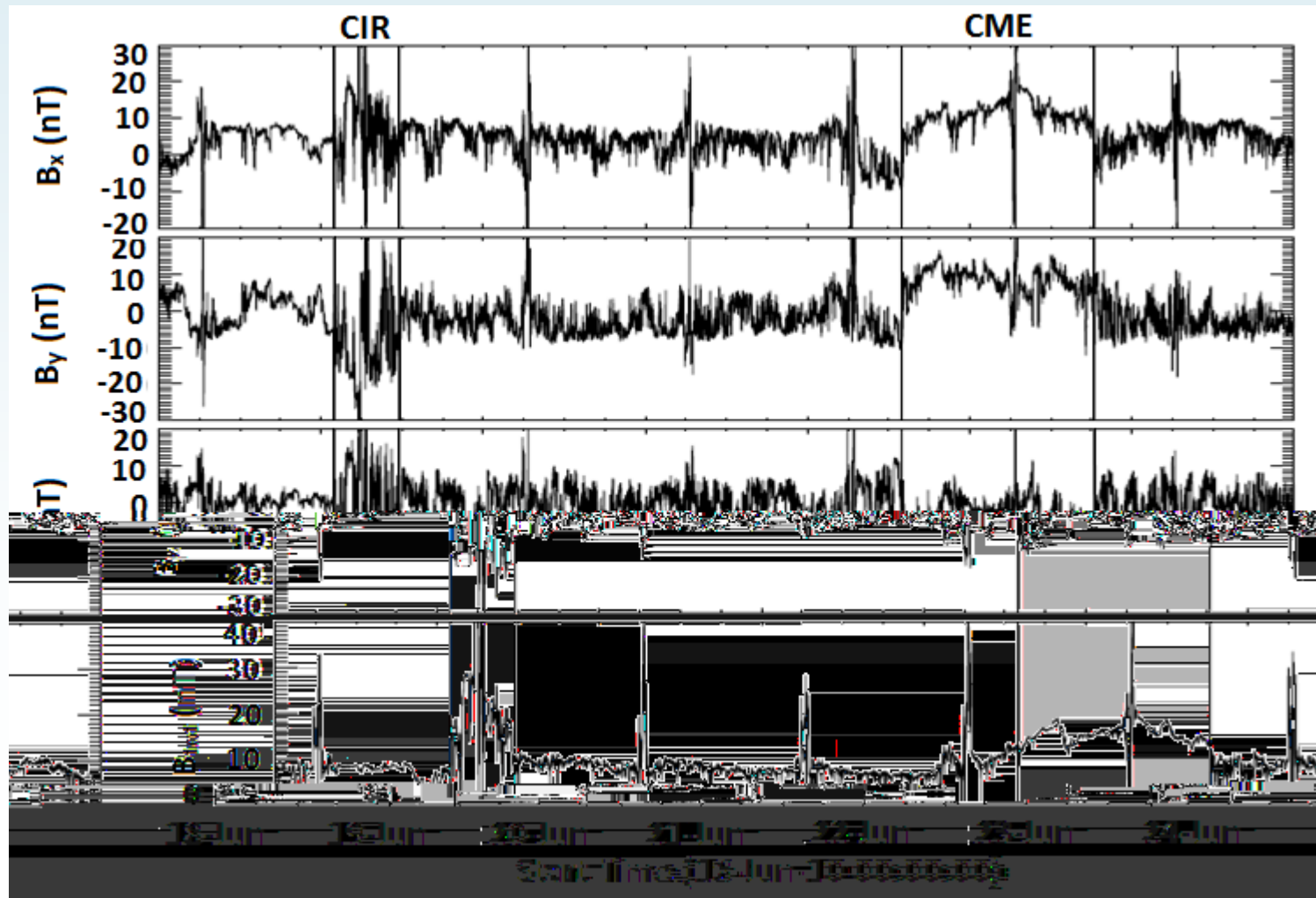
CME erupts ~01:30 UT  
Measured speed  
~590km/s



# Venus

CIR arrival at 02:00 UT 19 June

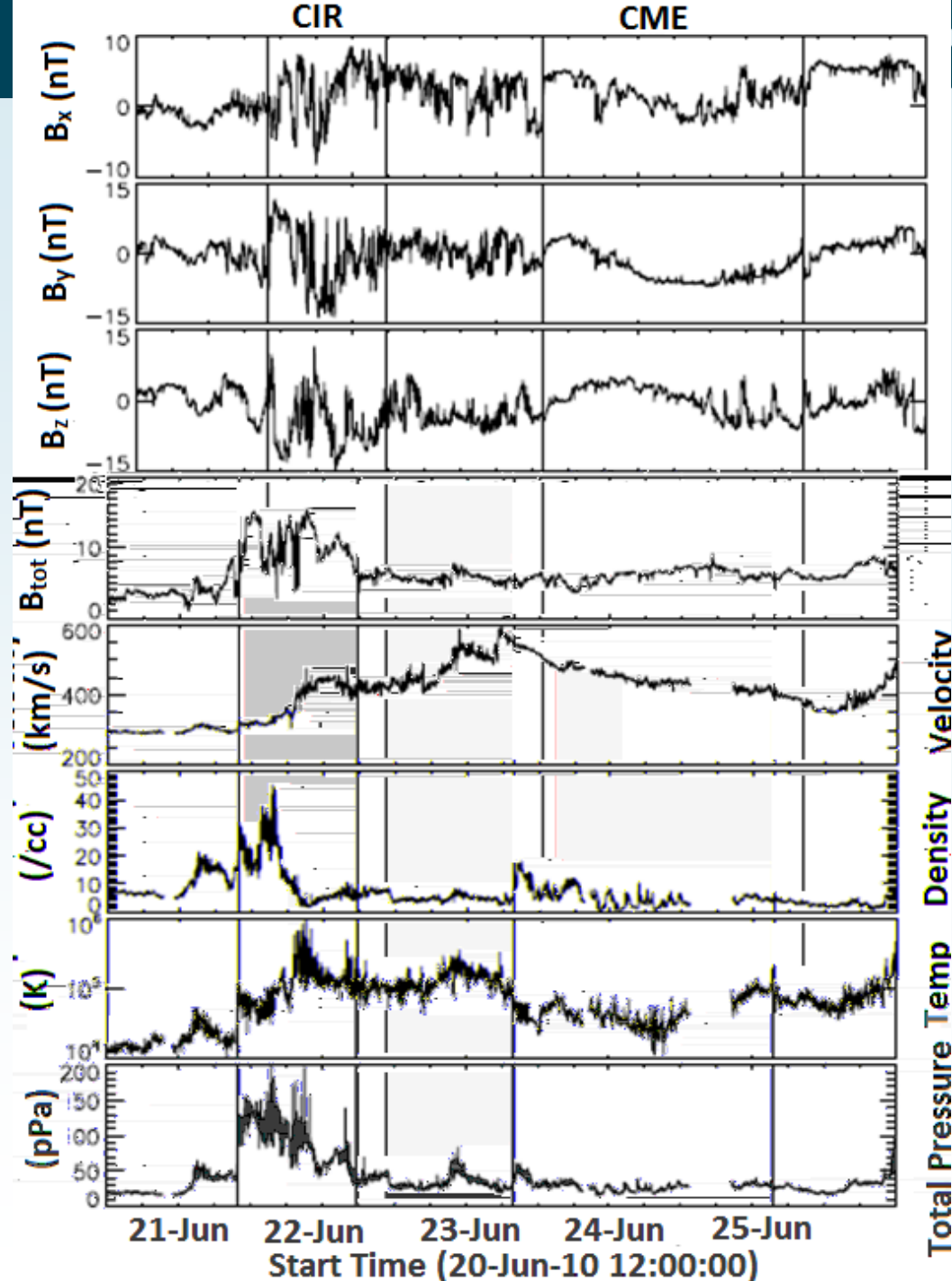
CME arrival at 14:00 UT 22 June



# STEREO-B

CIR arrival ~10:00  
21 June

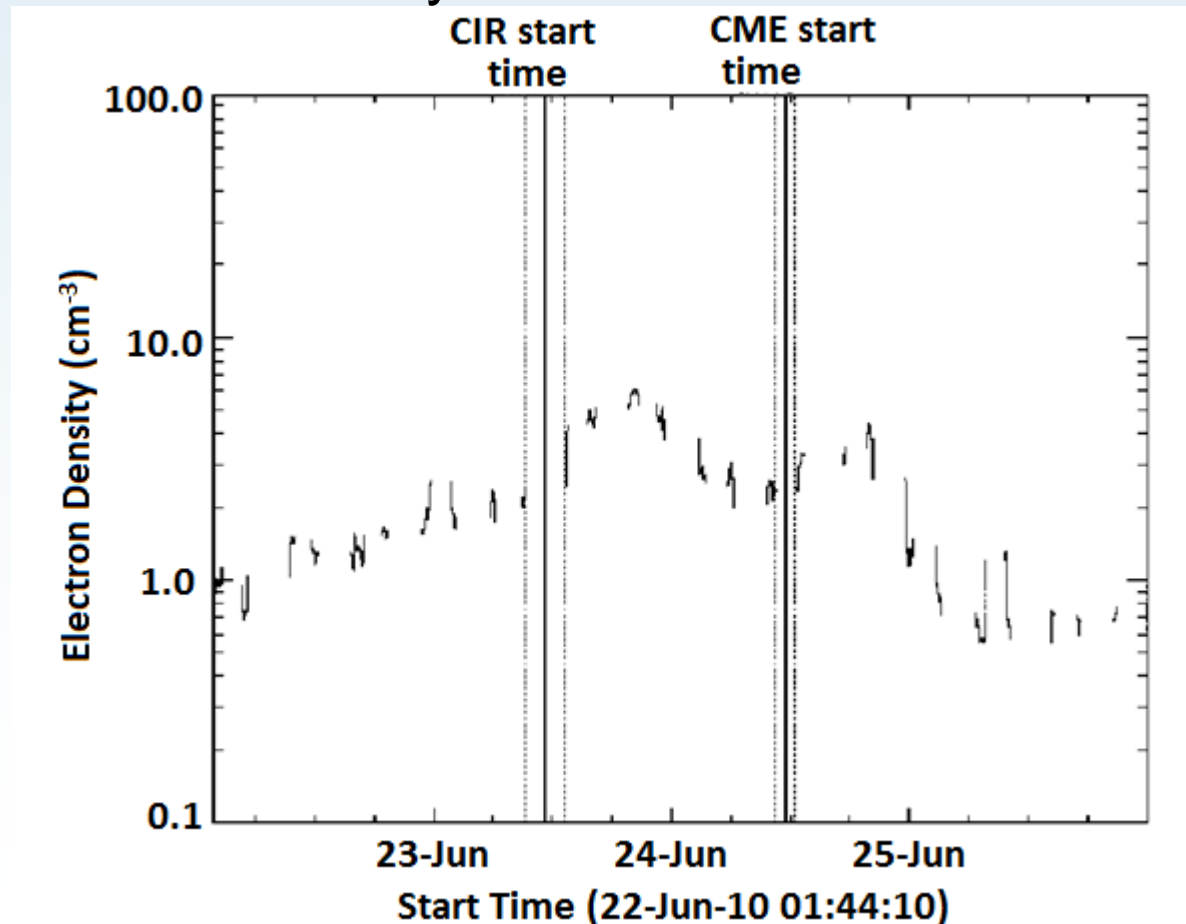
CME arrival  
~08:00 UT 23  
June



# Arrival at Mars

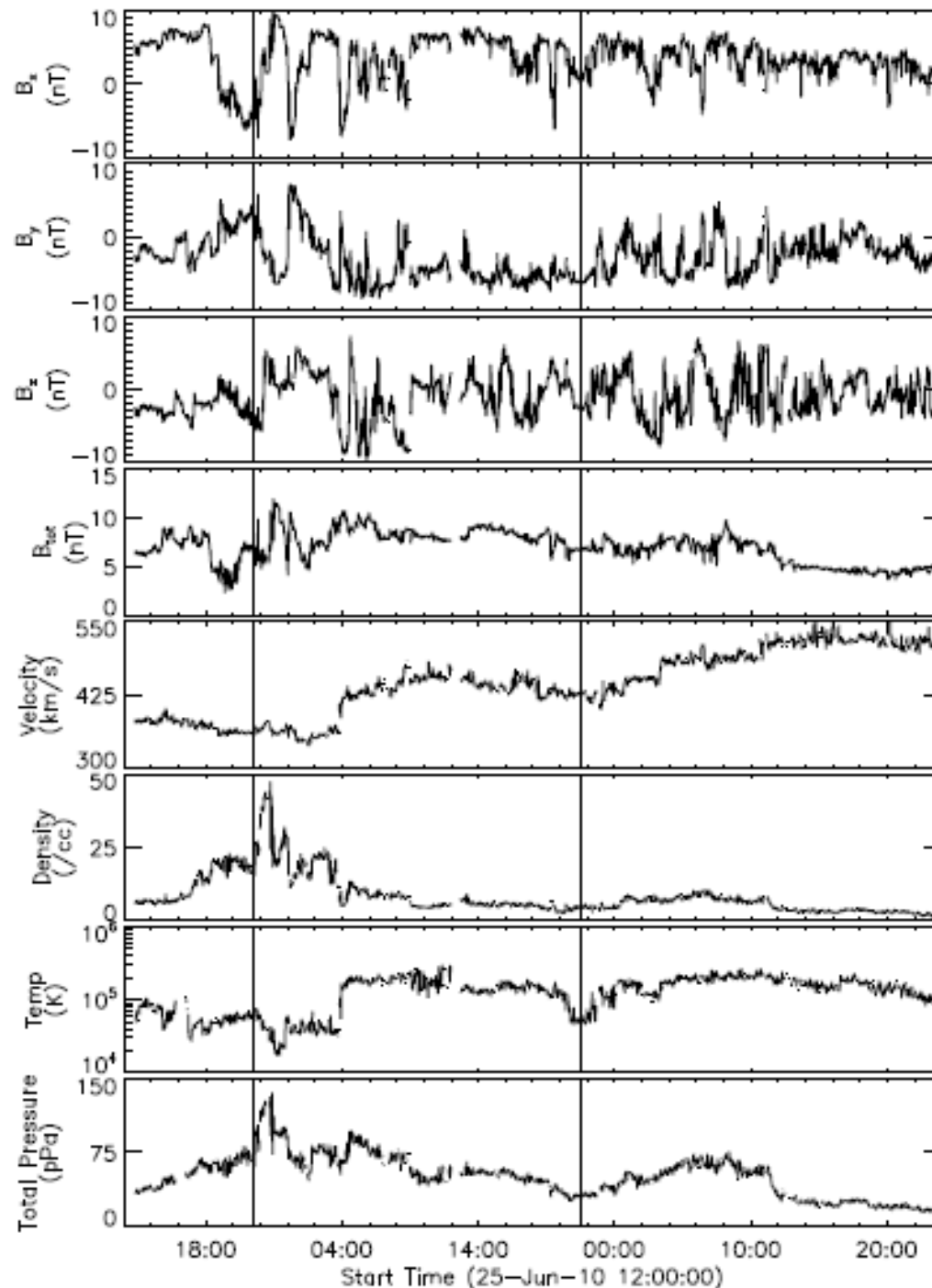
MEx has no magnetometer use plasma moments from ASPERA-3

2 peaks in density: middle of the day 23 June and 24 June



# CIR arrival at the Earth

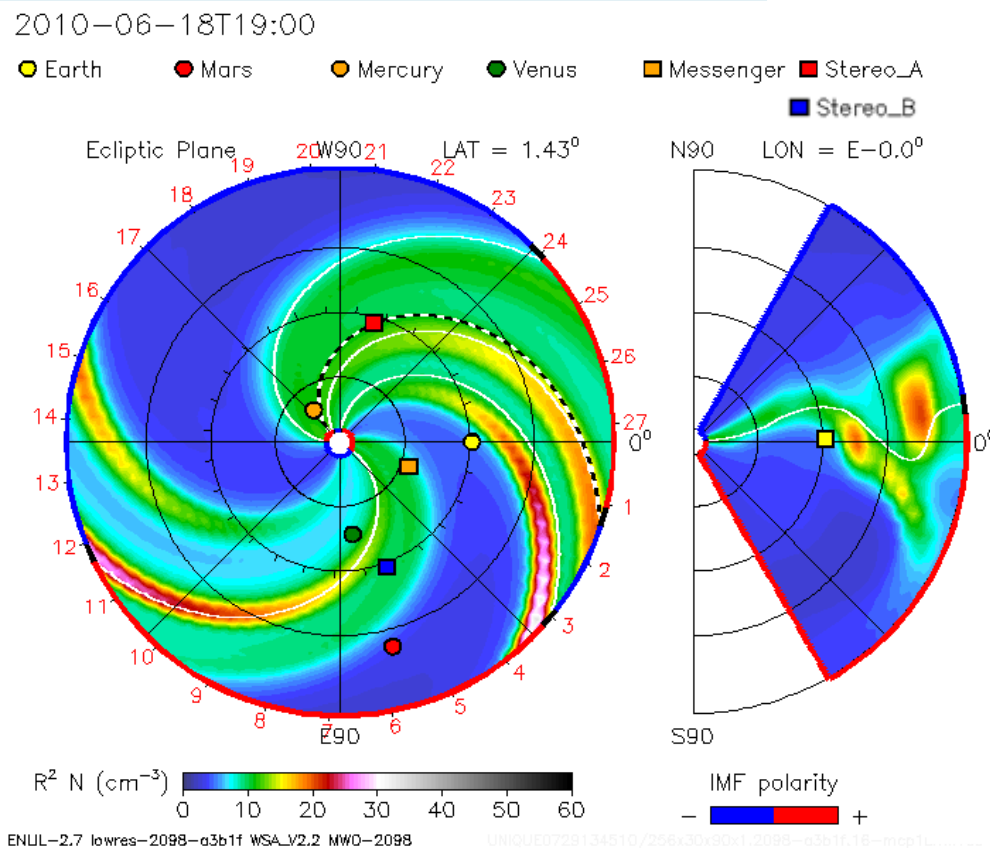
CME not directed towards Earth, but CIR passes 21:30 UT 25 June





# ENLIL+cone Modelling

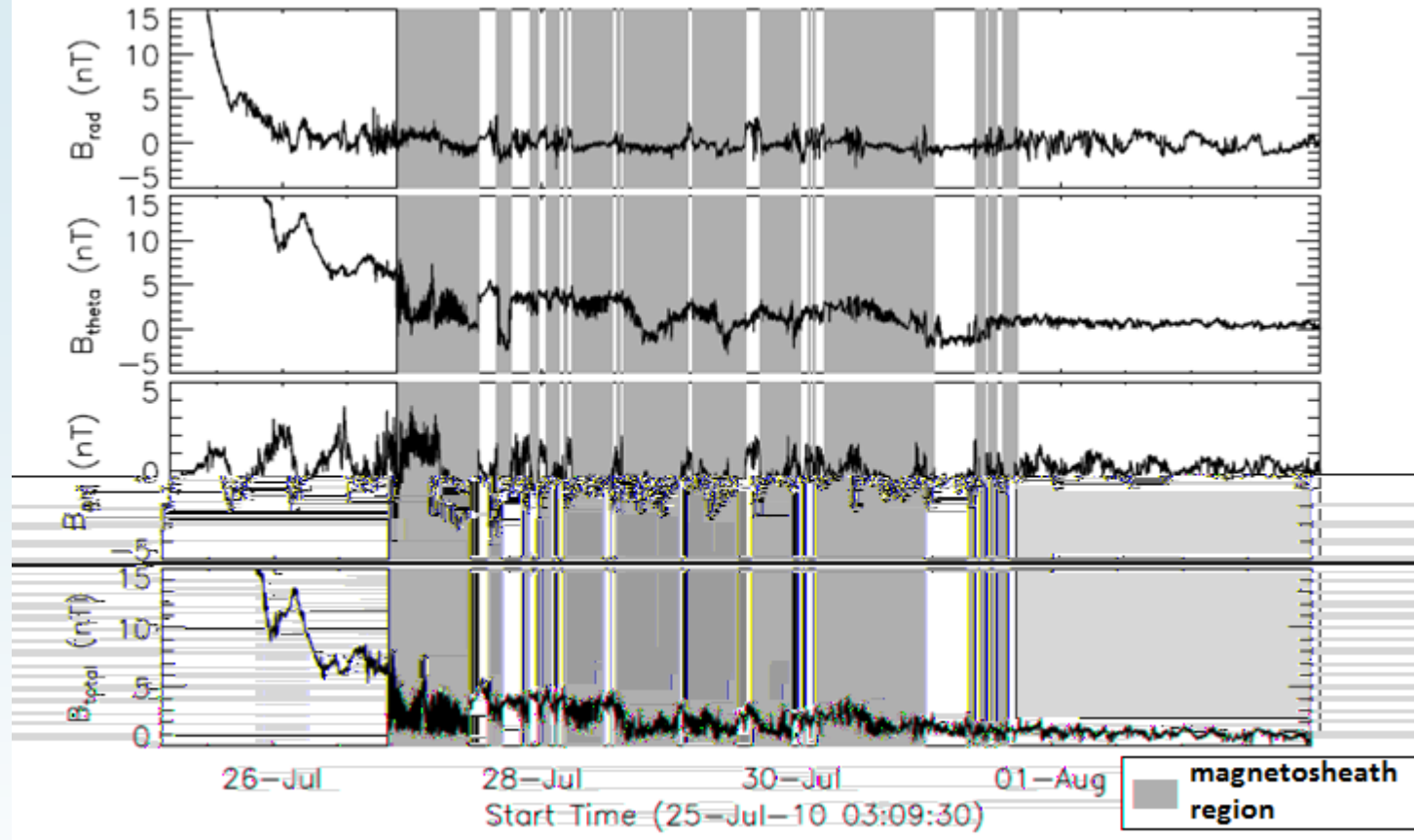
MHD model of solar wind, with cone model to add CME  
CIR then CME pass Venus, STEREO-B, Mars



In the outer solar system, ENLIL predicts the structures merge.  
Travel to Saturn and impact on 25 July 2010



# At Saturn



Cassini deep in magnetosphere 12:00 24 July 21:00 26 July

Enters magnetosheath early on outbound pass, indicating compression of magnetosphere

Model of magnetopause (Arridge et al. 2006) estimates the solar wind dynamic pressure at this time is 0.111 nPa and the magnetopause stand-off distance to be 16.0  $R_s$

# Timings Comparison

ENLIL arrival predictions of CME:

At Venus: -12 hrs

At ST-B: -1.5 hrs

At Mars: +19.5 hrs

ENLIL arrival predictions of CIR:

At Venus: -57 hrs

At ST-B: -57 hrs

At Mars: -52 hrs

At Earth: -36.5 hrs

ENLIL predictions show CME slowing down,



# Travel time prediction for CIR arrival (Williams et al., 2011)

$$= \frac{\Delta r}{V_r} + \frac{r_{\text{sun}}}{V_r}$$

= difference in radial distance

$\Delta r$   $r_{\text{sun}}$

From ST-B:

$V_r$  = mean CIR velocity

$\omega_{\text{sun}}$  = rotational rate of the Sun

At Venus: +3.5 hrs

At Mars: +3.5 hrs

At Earth: +7 hrs

From Earth:

At Venus: -0.5 hr

At ST-B: -7.5hr

At Mars: -9 hrs

Predictions closer than ENLIL, but requires more input information

## Summary

CME observed from the Sun to Venus, STEREO-B and Mars

CIR also observed at all 3 locations prior to CME and at Earth

ENLIL modelling shows CME merging with CIR

Saturn magnetosphere compression, could be consistent with impact of merged structure

ENLIL predictions of CME arrival times better than CIR

Travel time method yields better CIR predictions

CME accelerates in inner solar system, in contrast to ENLIL simulation.